INSTRUCTION MANUAL

FOR

QSB SERIES

100- WATT UNITS

Sorensen

POWER SUPPLIES

Manual No. 14-6309

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INSTRUCTION MANUAL
FOR
QSB SERIES
100- WATT UNITS

Manual covers QSB Models:

6-15	18-6
12-8	28-4

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SECTION I

INTRODUCTION AND DESCRIPTION

1-1. INTRODUCTION.

1-2. This manual provides operation and maintenance instructions for 100-watt QSB series power supplies, manufactured by Raytheon Co., Sorensen Operation. Specifically, the term "100-watt" unit refers to QSB models 6-15, 12-8, 18-6, and 28-4.

1-3. The manual is subdivided into six sections and an appendix. Section I contains a description of the units, as well as a tabular listing of complete unit specifications. Details on initial inspections and checkout procedures are given in Section II. Operating instructions, including methods for adapting units for various applications, comprise Section III. Sections IV and V provide the principles of operation and maintenance procedures, respectively. A replacement parts list forms Section VI, and the Appendix illustrates the extended range characteristics of each unit.

1-4. DESCRIPTION.

1-5. The typical QSB 100-watt unit accepts inputs from 105 to 125 V, over a frequency range of 50 to 400 Hz, and provides a highly regulated, precise d-c output. The unit reacts rapidly to load and line excursions, and exhibits very low output ripple. (Refer to Table 1-1 for complete specifications on all units.)

1-6. The use of silicon transistors gives the unit its wide ambient-temperature operating range and, as a maintenance feature, reduces the number of components. These components are protectively packaged in a compact, sturdy, cold-rolled-steel case, which is finished in a baked-on, gun-metal grey enamel. High-dissipation components are mounted on extrusion-type heat sinks and are cooled by convection.

1-7. Equally suitable for rack mounting or bench use, the QSB features an anodized aluminum front panel which mounts all of the operating controls used under normal conditions. These include an input power switch and a voltage adjust potentiometer. A power-on indicator is also provided. In addition, the front panel mounts a set of binding posts, including a ground, from which the unit output may be taken. (The output is also available at a set of terminals located on the rear-mounted terminal board.) Moreover, knob-operated holders have been located on the front panel to facilitate fuse checking and replacement. Safety features include a grounded chassis (when the power-cord plug is properly used.)

1-8. In addition to its many fine electrical and mechanical characteristics, the unit features a variety of operating configurations to service numerous applications. These features include remote sensing, constant-current operation, series and parallel operation and remote programming.

1-9. REMOTE SENSING. Terminals located on the rear-mounted terminal board offer the means of extending the unit's regulating point from the output terminals to the load. This, in effect, compensates for the IR drop in the load lines. QSB units will compensate for a drop in each leg equal to, at a minimum, 20 percent of the nominal output voltage.

1-10. CONSTANT CURRENT. The unit is easily adapted from its normal constant voltage mode to a constant current configuration. In this configuration, the output current is regulated at some constant value while the dynamic (compliance) voltage varies with the load. The regulation in constant current operation is $\pm 0.01\%$.

1-11. SERIES OPERATION. For applications requiring output voltages higher than any single QSB can supply, a number of QSB units may be connected in series to provide a maximum out-

	ALL MODELS (7)	6-15	12-8	18-6	28-4
Input Ratings					
Voltage Range (Vac)	105-125/200-240/ 210-250				
Frequency (Hz) (1)	50-400				
Phase	Single				
Max. Current (A ac)					
at 115 Vac	3				
at 230 Vac	1.5				
Power Factor (typical)		0.83	0.84	0.83	0.82
Efficiency (typical) (%)		35	46	53	44
Output Ratings					
Voltage Range (Vdc)		5.4-6.6	10.8-13.2	16.2-19.8	25.2-30.8
Extended Voltage Range		5-9	9-18	13-26	18-36
Resolution (mV) (typical)		36	54	72	92
Max. Current (Adc) at 55°C (2)		15	8	6	4
Extended Range Derating	see Appendix				
Current Mode Range (Adc)	0.1 - I_o max.				
Regulation (%)					
Voltage Mode (3)		±0.015	± 0.005	± 0.005	± 0.005
Current Mode (4)	± 0.01				
Temperature Coefficient					
Voltage Mode (Typ)(%/°C)	0.015				
Transient Response (µS) (5)		40	30	25	25
Output Voltage Turn-On and Turn-Off Overshoots	None				

(1) All applicable electrical specifications are guaranteed at 60 Hz.
(2) Max. current at 40°C is 110% I nominal and at 71°C is 75% I nominal.
(3) For combined full line and load change.
(4) For combined full line and 50% load change.
(5) For a step load change NL to FL or FL to NL and recovery to within ± 10 mV band.

Table 1-1. Unit Specifications (Sheet 1 of 2)

	ALL MODELS[7]	6-15	12-8	18-6	28-4
Ripple					
Voltage Mode					
Max. RMS Ripple (μV)	250				
Typ. Peak-to-Peak (mV)					
50 - 60 Hz	1				
400 Hz	5-20				
Current Mode	0.0025% of I_o max.				
Ambient Temperature Range (°C)	0 - 71				
Remote Programming (typ) (Ω/V)		15.5 ± 1	13 ± 2	13 ± 2	13 ± 2
Output Impedance (μΩ + L)		38 + .3 μh	50 + .3 μh	150 + .3 μh	250 + .3 μh
Stability (typical)					
8 hr. after warm-up	0.025% of E_o				
Thermal drift after					
NL to FL change (%)	0.08% of E_o				
Series Operation	Max. of 200 V				
Parallel Operation (Typ)[6]	Max. of 20 units				
Remote Sensing	20% E nominal in each leg (min)				
Cooling	Convection				
RFI Characteristics (typ)	Meets Mil-I-26600, Mil-I-6181D and Mil-I-16910C				
Dimensions (in.)					
Height	3-15/32				
Width	19				
Depth	12-1/2				
Weight (lb)	26				

(6) Derate each unit to 90% of maximum current. (7) Output specifications are applicable at rear terminals only.

Table 1-1. Unit Specifications. (Sheet 2 of 2)

put of 200 volts. Regulation in series operation is the sum of the regulation of all units.

1-12. PARALLEL OPERATION. Parallel operation may be used to service those applications requiring a higher output current than any single QSB can provide. Paralleling is indirect through a "master-slave" approach. The maximum number of units which may be paralleled is 20.

1-13. REMOTE PROGRAMMING. Some applications require that step changes be made in the unit output from remote locations. To service these, the unit has been made adaptable to remote programming. The adapting procedure entails only the connection of a calculated resistor or resistors into the programming circuit. Sensitivity for six-volt units is 15.5 $\pm$ 1 ohms/volt; sensitivity for all other units is 13 $\pm$ 2 ohms/volt.

1-14. OPTIONAL EQUIPMENT.

1-15. The QSB 100-watt units may be purchased equipped with both an output voltmeter and an output ammeter. These meters, for a particular unit, feature ranges expressly designed for compatibility with unit output ratings.

SECTION II

PREPARATION FOR USE

2-1. GENERAL.

2-2. After unpacking, initial inspections and preliminary checkout procedures should be performed to assure that unit is in good working order. Basically, these consist of visually checking for damaged parts and components, and of making an electrical check. If it is determined that the unit is damaged, follow the instructions on the Damage and/or Loss in Shipment form enclosed with the unit, and notify the carrier immediately. The carrier's claim agent will then prepare a report of damage. The user is required to send this report to the Service Dept., Raytheon Company, Sorensen Operation, Richards Avenue, Norwalk, Conn. Sorensen will, in turn, advise the user as to what action is required to repair or replace the supply.

2-3. In addition to inspection and check-out procedures, this section contains instructions to adapt unit for rack use and on altering unit input wiring for either 220 or 230 volt operation.

2-4. INITIAL INSPECTION.

2-5. Proceed as follows to inspect for damage incurred during shipment:

a. Inspect panel and chassis for dents, chips and other signs of structural damage.

b. Check action of fuseholders. Assure that each holder contains a properly rated fuse. Fuse current ratings are printed on front panel below holders.

c. Turn VOLT ADJUST potentiometer from stop-to-stop. Rotation should be smooth through a 300-degree angle.

d. Alternate POWER Switch to ON and OFF a few times. Snapping action should be both positive and audible. Terminate check with switch in OFF position.

e. Inspect power input cord for obvious signs of damage. Tug lightly on cord near chassis to assure that relief grommet grips cord.

f. Check terminal board. Assure that links are firmly in place across terminals 1 and 2, 3 and 4, 5 and 6, and 7 and 8.

g. Remove screws retaining top cover to chassis. Inspect components for signs of physical damage. If unit is to be rewired for an alternate input, proceed to para 2-6 before remounting cover.

2-6. ELECTRICAL INSTALLATION.

2-7. QSB units are wired to accept a 115 Vac supply. However, either of two alternate inputs may be used by making a few wiring changes. The following two paragraphs describe the procedures.

2-8. 220-VOLT OPERATION. To alter the unit from 115 V to 220-volt operation, see Figure 2-1 and proceed as follows:

a. At transformer T1, unsolder or cut jumpers across taps 1 and 3, and 2 and 4.

b. Solder a jumper across taps 2 and 3.

c. Unsolder yellow wire at tap 4 and relocate to tap 11.

d. Replace fuse F1 with a 2.5 A rated fuse (Littelfuse, Inc. P/N 31202.5).

e. Remount cover.

2-9. 230-VOLT INPUT. To alter unit from 115 to 230-volt operation, see Figure 2-1 and proceed as follows:

a. At transformer T1, unsolder jumpers across taps 1 and 3, and 2 and 4.

b. Solder jumper across taps 2 and 3.

c. Replace F1 with a 2.5 A rated fuse (Littelfuse Inc., P/N 31202.5).

d. Remount cover.

2-10. INPUT POWER CORD. The input power cord terminates externally in a three-prong polarized plug. The unit chassis is wired to the plug through the line cord, and therefore, the insertion of the plug into a compatible receptacle, hooked up to a grounded input will automatically ground the unit. If a grounded input is not available, use an adapter, making sure that the adapter's external lead is well-grounded.

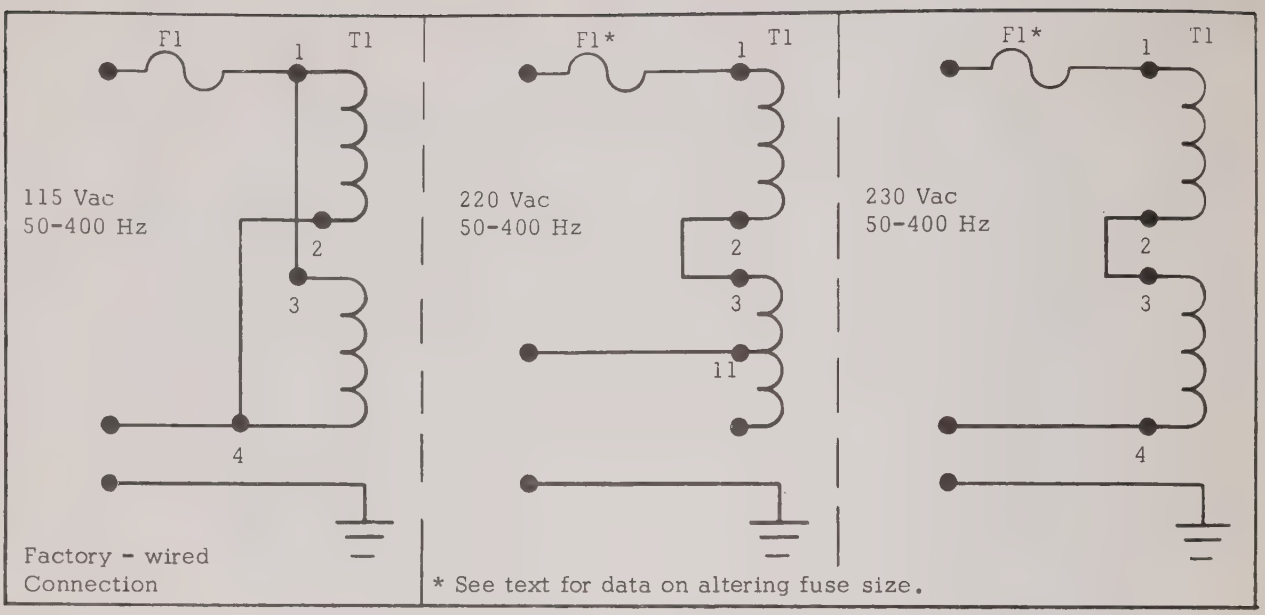


Figure 2-1. Alternate Input Connections.

2-11. ELECTRICAL INSPECTION.

2-12. To perform an initial electrical inspection, proceed as follows:

a. Install line cord plug into a suitable receptacle. (Refer to para 2-10.)

b. Turn VOLT ADJUST potentiometer control fully counterclockwise.

c. Connect a d-c voltmeter across "+" and "-" binding posts on front panel, or across terminals 6 and 7 on rear-mounted terminal board. Select a voltmeter range compatible with rated unit output.

CAUTION

Do not remove or loosen any terminal interconnecting links.

d. Set POWER switch to ON. Voltmeter should indicate, at a maximum, unit low-end rated output.

e. Rotate VOLTAGE ADJUST control fully clockwise. Voltmeter should indicate, at a minimum, unit high-end rated output.

f. Set POWER Switch to OFF, and disconnect voltmeter.

2-13. MECHANICAL INSTALLATION.

2-14. The unit is shipped ready for bench use. However, it may be adapted for rack mounting by simply removing unit feet. Rack mounting holes are located on both sides of front panel.

SECTION III

OPERATING INSTRUCTIONS

3-1. GENERAL.

3-2. This section, in addition to providing basic operating instructions, details the methods by which QSB's may be adapted to their more common applications. These include remote sensing, remote programming, and series, parallel and current-mode operation. Table 3-1 and Figure 3-1 respectively describe and show the location of unit operating controls and indicators.

CAUTION

The QSB is cooled by convection. Locate in an area where the free flow of air around and through unit is unimpeded.

CONTROL/INDICATOR	FUNCTION
POWER Switch	A double-pole, single-throw switch used to connect a-c input to primary of main transformer T1.
VOLT ADJUST Potentiometer	Connected in series with the sensing network and across the output terminals, this control, when rotated, varies the unit output voltage.
POWER Light	A red lamp which, when glowing, indicates input power is being applied to primary of transformer T1.
Unit Voltmeter	An optional meter which indicates unit output voltage. Connected internally across the "SENSE" terminals.
Unit Ammeter	An optional meter connected in positive output leg. Indicates unit load current.

Table 3-1. Controls and Indicators.

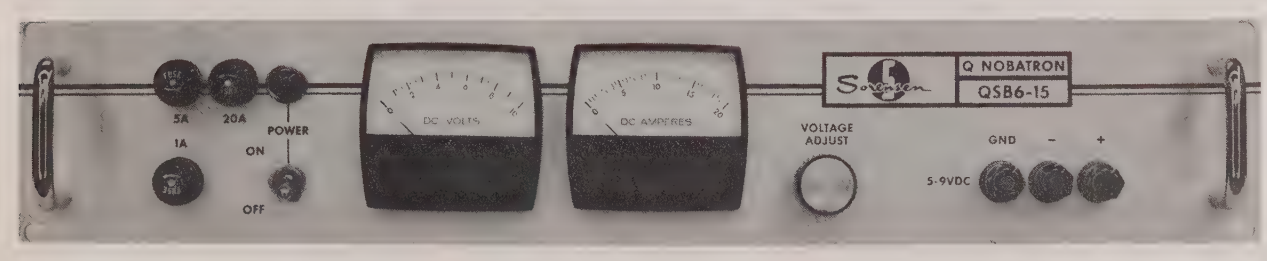


Figure 3-1. Typical Control Panel.

3-3. LOCAL SENSING.

3-4. The unit is shipped ready for use in the local-sensing configuration. With this hook-up, unit output is regulated at the output terminals, with no compensation for load losses. If these drops are expected to be prohibitive, use the remote-sensing configuration as outlined in para 3-7.

3-5. To operate the unit, proceed as follows:

a. Connect a voltmeter across terminals 5 and 8. Select a meter range compatible with unit's rated output.

b. Insert line cord plug into a suitable receptable (refer to para 2-10).

c. Set POWER Switch to ON. POWER light glows.

d. Rotate VOLT ADJUST knob until desired output voltage is indicated on voltmeter.

e. Set POWER Switch to OFF and disconnect voltmeter. Tighten terminal screws.

f. Connect load leads to terminal 6 and 7, positive lead to terminal 6 and negative lead to terminal 7.

g. Set POWER Switch to ON. POWER light glows and unit supplies highly regulated power to load.

3-6. REMOTE SENSING.

3-7. If it is desired to sense (regulate) the unit output at load rather than at output terminals, remove links between terminals 5 and 6, and 7 and 8. Next, run a sensing lead from terminal 5 to positive side of load; connect another lead from terminal 8 to negative side of load (see Figure 3-2). Use either coaxial cable or a pair of twisted wires for sensing leads. Put unit into operation per para 3-5. Some degeneration in response time is inherent in remote-sensing operation. If it is critical that response time meet specifications, disconnect output capacitor C7 and reconnect it, or an identical capacitor, locally across the load. Rating of C7 may be determined from replacement parts list in Section VI.

3-8. REMOTE PROGRAMMING.

3-9. The procedure in which a calculated resistance is introduced into the sensing network in order to obtain a predetermined output is called remote programming. Its use is advantageous in those applications where unit output must be controlled from remote locations.

3-10. The programming sensitivity is 15.5 ± 1 ohms/volt for six-volt units and 13 ± 2 ohms/volt for all other units. This means that for each volt difference between the minimum value of the unit's extended range and the desired output voltage approximately 15.5 ohms are required for six-volt units and 13 ± 2 ohms are needed for all other units. In selecting a programming resistor, choose one which has a low temperature coefficient (± 30 ppm) and a wattage rating at least ten times that calculated. Programming current is 70 mA maximum for six-volt units, and 90 mA maximum for other units.

3-11. To adapt unit to remote programming operation, proceed as follows:

a. Set POWER Switch to OFF.

b. Turn VOLT ADJUST knob fully counterclockwise.

c. Remove link between terminals 3 and 4 (CUR REG.) and connect programming resistor (previously calculated) across terminals. (See Figure 3-3.) Do not use alligator clips or re-

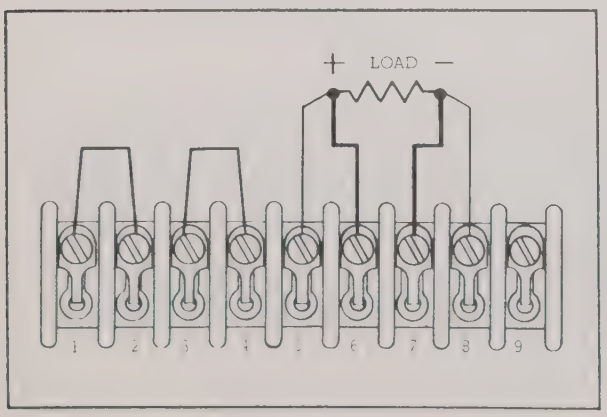


Figure 3-2. Remote Sensing Configuration.

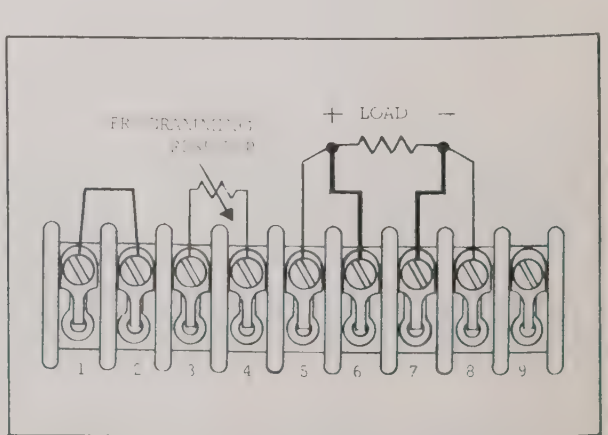


Figure 3-3. Remote Programming Set-up.

lated types of connecting devices for programming resistor. Turn down terminal screws until a good, firm connection is made to resistor leads.

d. Connect load to terminals 6 and 7, positive side at 6, negative at 7. Use remote sensing, if desired.

e. Set POWER Switch to ON. Power light glows. If desired, check output with a voltmeter.

Note

Turning the VOLT ADJUST knob will increase the output voltage. It this is an undesirable feature, the VOLT ADJUST control may be by-passed by first removing the link between terminals 3 and 4 and then connecting the programming resistor between terminals 3 and 8, in series with the programming resistor. (For 18-volt units, add 40 ohms to programming resistance. An additional 90 ohms must be added to the resistance in 28-volt units.)

3-12. CONSTANT PROGRAMMING. Programming current in a particular unit is constant due to the constant load presented by the sensing bridge and amplifier. This current, however, may not be, and probably is not, identical with the programming current in any other randomly selected unit. This is attributable to dissimilarities, within acceptable tolerances, in component characteristics.

3-13. For those applications where a constant ohms/volt is required, the sensing bridge may be modified to obtain the necessary constant programming current from unit-to-unit. Select a 1000-ohm potentiometer with a low temperature coefficient (± 30 ppm), and connect internally as a rheostat across potentiometer R15. Rotate 1000 ohm potentiometer shaft fully clockwise. Remove link between terminals 3 and 4, and connect a milliammeter across terminals. Apply input power; then rotate 1000 ohm potentiometer shaft until 100 mA are indicated on meter. Disconnect input power and meter. Repeat entire procedure for all other units. The programming sensitivity is now a constant 10 ohms/volt. Use this value to determine value of programming resistor (para 3-10). Hook up resistor per para 3-11.

Note

The programming current for six-volt units is 70 mA, max. Therefore, if a programmed system contains only six-volt units, the ohms/volt sensitivity may be made a constant 12.5 ohms/volt by using a 750 ohm potentiometer and obtaining an 80 mA current on test ammeter.

3-14. SERIES OPERATION.

3-15. Series operation may be used to obtain output voltages higher than the maximum extended range of any one unit. The maximum output rating of any series-connected system is 200 volts. Regulation in series operation is the sum of the specified regulation for each unit. The maximum output current of a series-

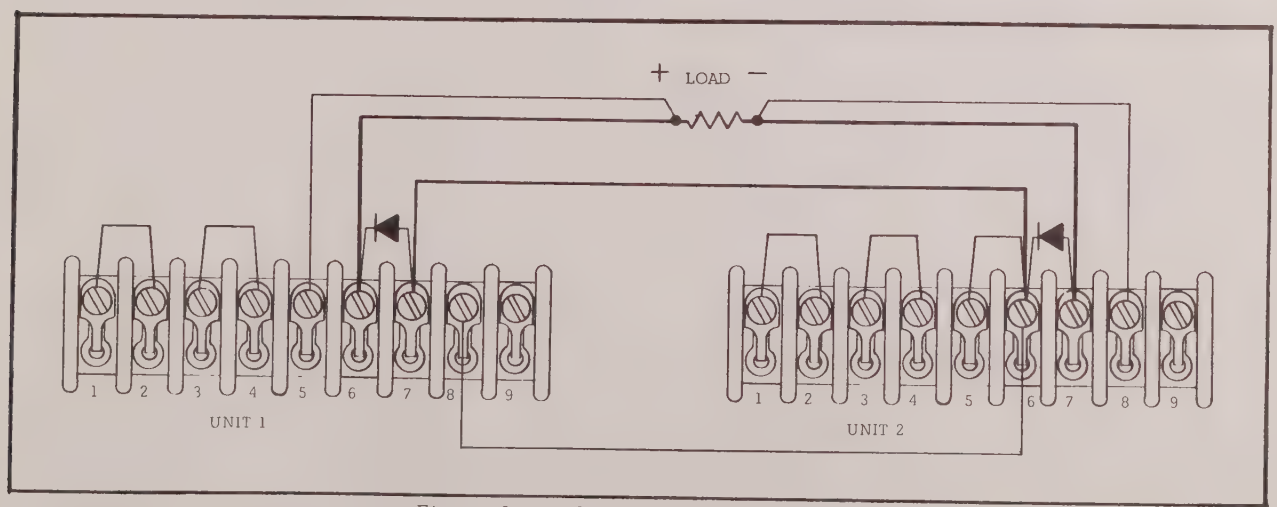


Figure 3-4. Series Operation Hook-up.

connected system is limited to the maximum current output of the lowest rated supply.

3-16. The following outlines procedures for connecting two QSB's in series (see Figure 3-4). The procedure need only be extended to series connect as many units as desired within the limitations given in para 3-15.

a. Set POWER Switches of both units to OFF.

b. Remove links between terminals 5 and 6, and 7 and 8, unit 1. Remove link from terminals 7 and 8, unit 2.

c. Connect load lead from terminal 7, unit 1, to terminal 6, unit 2.

d. Run a load lead from terminal 6, unit 1, to the positive side of load.

e. Connect a load lead from terminal 7, unit 2, to negative side of load.

f. Run a sensing lead from terminal 8, unit 1, to terminal 6, unit 2.

g. Connect a sensing lead from terminal 5, unit 1, to positive side of load; run another sensing lead from terminal 8, unit 2, to negative side of load.

CAUTION

To protect the units' output capacitors, connect a rectifier across individual unit output terminals (see Figure 3-4). Refer to para 3-17 for rectifier recommendations.

3-17. RECTIFIER RECOMMENDATIONS. In series operation, a rectifier should be connected across the output terminals of each unit to protect the output capacitor in the event of a unit failure. Rectifiers recommended for this purpose are listed in Table 3-2. Flat aluminum plate, 0.32-in thick, should be used for heatsink.

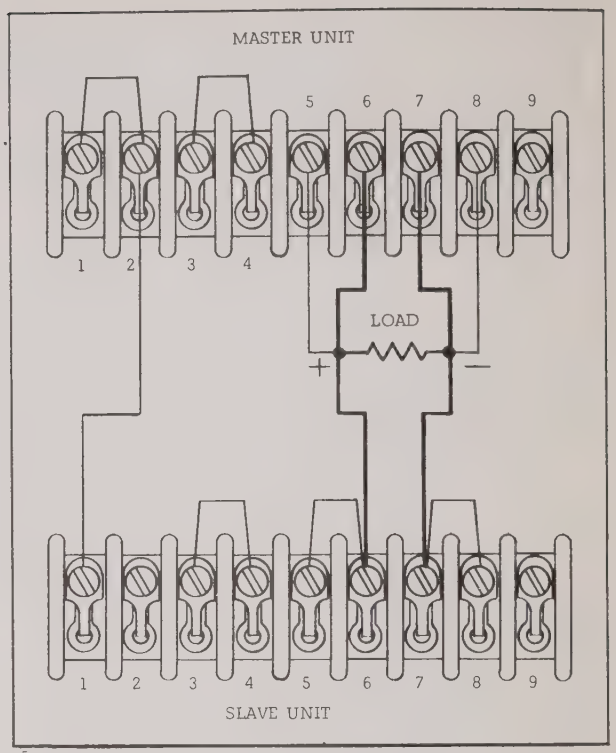


Figure 3-5. Parallel Operation Hook-up.

3-18. PARALLEL OPERATION.

3-19. Loads which draw currents higher than the rated output of any single QSB unit may be serviced by paralleling units. Readily accessible terminals at unit rear facilitate the paralleling procedure. QSB parallel operation is based on the "master-slave" concept, i.e., amplifier of the "master" unit supplies drive current to all "slave" units. ("Slave" unit amplifiers are disconnected during the paralleling procedure.)

3-20. The following outlines procedures for

QSB MODEL	MFR	TYPE	SORENSEN P/N	HEATSINK DIMENSIONS (in.)
6-15	Motorola	MR 1120 (1)	26-1046-1	3-1/4 x 3-1/4 (2)
12-8	Motorola	MR 1120 (1)	26-1046-1	2-1/4 x 2-1/4
18-6	Motorola	MR 1120 (1)	26-1046-1	1-1/2 x 1-1/2
28-4	Motorola	MR 1030A	26-1006-1	

(1) Mounting torque is 12-15 lb-in.
(2) Do not use washers to insulate rectifiers from heatsink.

Table 3-2. Rectifier Recommendations.

paralleling two units. However, this procedure need only be extended to parallel up to 20 units. Derate each unit to be paralleled to 90% of the maximum nominal output current. Maximum system output is the sum of the derated currents.

a. Set POWER Switches of both units to OFF.

b. Remove link between terminals 5 and 6, and 7 and 8 on "master" unit. Disconnect link between terminals 1 and 2, "slave" unit. (See Figure 3-5 for parallel operation hook-up representation.)

c. Connect a load lead from terminal 6 of each unit to positive side of load; run a load lead from terminal 7 of each unit to negative side of load.

d. Run a sensing lead from terminal 5, "master" unit, to load (+); connect another sensing lead from terminal 8, "master" unit, to load (-). Use coaxial cable or pair of twisted wires for sensing leads.

e. Connect a lead from terminal 1, "slave" unit, to terminal 2, "master" unit.

f. Set POWER Switches to ON. Only when all input switches in system are set to ON will output be available to load.

Note

Regulation degeneration is negligible in parallel operation.

3-21. CURRENT-REGULATING MODE.

3-22. The QSB is convertible from its normal voltage-regulating configuration to a current-regulating mode. In this mode, the unit output current is held constant, while the output voltage varies with load. Current regulation specifications are listed in Table 1-1.

3-23. The procedure for adapting the QSB to the current regulating mode is applicable to all units. However, before performing the actual procedure, two calculations must be made; one determines the unit's dynamic (compliance) voltage for the particular value of constant current, and the other gives the value and power rating for the required sensing resistor. Inasmuch as these calculations involve variables which can only be determined by the user, specific calculations for every possible combination cannot be given here. Therefore, only the general steps are provided along with an illustrative example. The specific procedure for hooking up the unit follows these.

3-24. CALCULATIONS. The following gives the general steps for calculating the dynamic voltage range and the value of sensing resistor (R):

a. Divide the desired value of constant current (I_c) by the nominal maximum rated output current (I_m) and multiply by 100, i.e.,

$$\text{Percent } I_{load} = (I_c/I_m) \times 100$$

b. Determine unit's input voltage.

c. On extended range characteristics (Appendix), plot the percent I_{load} (calculated in "a") on vertical % I_{load} line. Next, extend a horizontal line, from plotted point, to both left and right until line intersects with either vertical broken line or with applicable slanted input voltage line. Drop a line to the abscissa from points of intersection. Subtract 5 for six-volt units and 9 for all other units from value obtained at points. The minimum and maximum obtained define the dynamic (compliance) voltage range.

d. Next, calculate value of the sensing resistor. Use the relation:

$R = 5/(I_c - I_s)$ for 6-volt units (I_s = 70 mA);

$R = 9/(I_c - I_s)$ for all other units (I_s = 90 mA).

Determine power rating:

$$W_{rated} = (I_c^2 R) \times 10$$

3-25. For the illustrative example, assume the following: unit is a QSB 6-15, desired constant current is 13.5 A, and input voltage is 115 V ac.

a. Calculate percent I_{load}.

$$\text{Percent } I_{load} = (I_c/I_m) \times 100$$

$$= (13.5/15) \times 100 = 90$$

b. On Figure A-1, plot point 90 on the %I_{load} line. Extend line, as shown in Figure, to left and to right. Line to left intersects broken line. Value on abscissa is 5. Line to right intersects applicable input voltage line (115 Vac). Value on Abscissa is 8.70 volts. Subtracting 5 from each value gives a dynamic voltage range of 0 to 3.70 volts.

c. Calculate value of sensing resistor.

$R = 5/(I_c - I_s) = 5/(13.5-.07) = 0.37$ ohms.

Next, calculate power rating:

$$W_{rated} = (I_c^2 R) \times 10 = 675 \text{ W}.$$

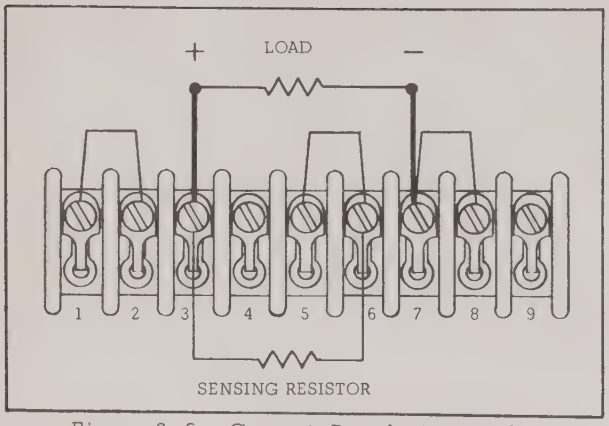


Figure 3-6. Current-Regulating Mode.

3-26. PROCEDURE. After performing the requisite calculations outlined in para 3-24, and finding a suitable resistor, proceed as follows:

a. Set POWER Switch to OFF.

b. Remove link across terminals 3 and 4. Assure that links across 1 and 2, 5 and 6, and 7 and 8 are secure.

c. Connect sensing resistor across terminals 3 and 6 (Figure 3-6.)

d. Connect a load lead from terminals 3 to positive side of load; run other load lead from terminal 7 to load (-).

e. Set POWER Switch to ON. If desired, check current with a suitable ammeter.

SECTION IV

PRINCIPLES OF OPERATION

4-1. GENERAL.

4-2. This section discusses the basic principle of the series-passing-stage power supply, describes the block functions of several QSB circuits and then treats each of these sections in detail. If used as a supplement to the maintenance data provided in Section V, an understanding of the material herein will aid in the rapid and logical isolation of unit faults.

4-3. BASIC THEORY.

4-4. The QSB utilizes the series-passing stage principle in regulating unit output. With this approach, a variable impedance absorbs the difference between the desired regulated output and the filtered "brute-force" dc. The variable impedance is provided by a transistor stage which is fed a control signal that is related to the unit output. This transistor is known as the series passing stage since it is connected in series with the load and must pass all load current. Figure 4-1 presents an idealization of passing stage operation.

4-5. BLOCK DIAGRAM DISCUSSION.

4-6. The following discusses, in a general manner, the internal operation of a QSB. A more detailed treatment of the various sections is presented in subsequent paragraphs. Refer to Figure 4-2: the a-c input is stepped-down by the input transformer and applied across a full-wave, center-tapped rectifier. Output from the rectifier is filtered and fed through the passing stage to the load. This passing stage is, of course, the regulating device, absorbing the difference between the rectifier and desired output voltages. The feedback loop to the passing stage includes a sensing bridge which compares a portion of unit output against a fixed reference to produce an error signal. Bridge derived error signals, differentially amplified, are used to alter the current path of constant-current generator output. This, in effect, varies the current drive to the passing stage, thereby changing stage impedance (and therefore IR drop) as a function of unit output.

4-7. SENSING AND ERROR AMPLIFICATION.

4-8. Output-voltage sensing and error amplification are provided by a bridge circuit, made up of resistor (R9), zener diode (CR8) and potentiometer (R15), and differential amplifiers (Q8, Q9 and Q6, Q7). See Figure 5-3 for schematic locations of parenthetic reference designations used through this section.

4-9. The voltage reference, provided by the zener action of CR8, is compared with a portion of the output voltage sensed across an arm of the bridge, i.e., schematically the part of R15 across the base-emitter of Q9. Comparison error signals, resulting from variations in unit output, are applied to the bases of Q8 and Q9. As a result, the operating currents in each transistor change as a function of signal strength. The sum of these currents is kept approximately constant by the large resistance of R13. Therefore, an increase in current through one transistor results in an accompanying decrease in current through its companion device. Such action causes a change in signal currents to the bases of Q6 and Q7, e.g., if Q9 conducts more, the base-emitter voltage of Q7 is reduced. The collector current of Q7 diminishes and Q6 collector current increases.

4-10. The voltage across (R15) and therefore across the sensing bridge is actually the voltage being regulated. It is therefore very nearly con-

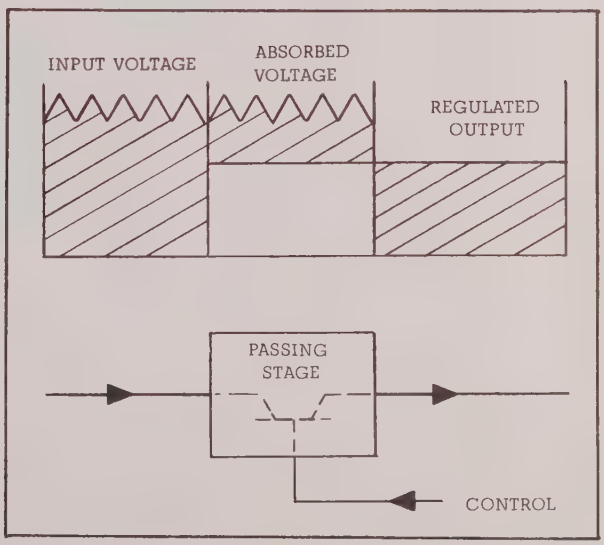


Figure 4-1. Series Passing Stage Principle.

stant. As a result, the total of the bridge and amplifier currents is constant. This total current produces an IR drop across R18 which, when added to the voltage across R15, gives the output voltage. It is just a simple application of Ohm's law to show that, with a constant current through R18, changes in R18 will vary the unit output voltage.

4-11. CONSTANT-CURRENT GENERATOR.

4-12. In para 4-9, it was stated that the conduction level of Q6 is controlled by the operation of differential amplifier (Q8,Q9). Current through Q6 then is altered indirectly by variations in output voltage. The sum of Q6's operating current and the drive current on the base of Q4 (or Q5) is held constant by the constant-current generator. As a result, controlled variations in the amount of operating current through Q6 are reflected as increases or decreases in drive current to the base of Q4 (or Q5 in QSB 6-15 units). This is the key to feedback control.

4-13. The constant current generator is comprised of two resistors (R1 and R2), two diodes (CR2 and CR3), and transistor (Q1). The diodes act as voltage regulators and provide the current limiting characteristic by holding the drop across R1 constant. Input to the generator is derived from a secondary of T1. CR1 provides half-wave rectification, and C1 acts as a filter.

4-14. DRIVERS AND PASSING STAGE.

4-15. Drivers for passing stage (Q2) are transistors Q3 and Q4 (and Q5 in QSB 6-15 units). As may be recalled, the constant current generator supplies drive current to Q4 (or Q5) and operating current for Q6. The drive current is amplified by a high-gain circuit (Darlington connection). The amplified current is then applied to the base of Q2, altering its impedance and therefore its IR drop as a function of unit output. This completes the feedback loop.

4-16. CIRCUIT OPERATION.

4-17. As an example of circuit operation, assume that the output voltage begins to increase above that desired. The voltage across R15 will also start to increase. Transistor Q9 sees this change as an increase in base-emitter voltage and goes into a state of higher conduction (lower impedance). The voltage drop across Q9 decreases. This decrease also appears in the base-emitter of Q7, since this junction is connected in parallel with Q9. As a result, Q7 will conduct less. Q6 will conduct more due to the increased drop across Q8. As Q6 takes a larger share of the current from the constant-current generator, the current to the base of Q4 (or Q5) decreases. Decreasing the drive to Q4 (or Q5) lowers the drive to the passing stage (Q2). Q2's impedance then rises, increasing its absorbed voltage and decreasing the output voltage.

4-18. STABILIZATION.

4-19. Inherent in the operation of high-gain feedback amplifiers, such as those used in the QSB, is the tendency for the amplifier to become unstable under certain conditions. To preclude such an occurrence, a stabilizing network has been designed into the unit. It consists of capacitors C4, C5, C6, C7, C13 and C14.

4-20. AUXILIARY POWER.

4-21. QSB 6-15 units only have an auxiliary supply to provide power to drivers Q3, Q4 and Q5. It consists of a full-wave, center-tapped rectifier (CR4,CR5) and filter capacitor (C2). A-c input to the rectifier is derived from an additional secondary winding of transformer T1.

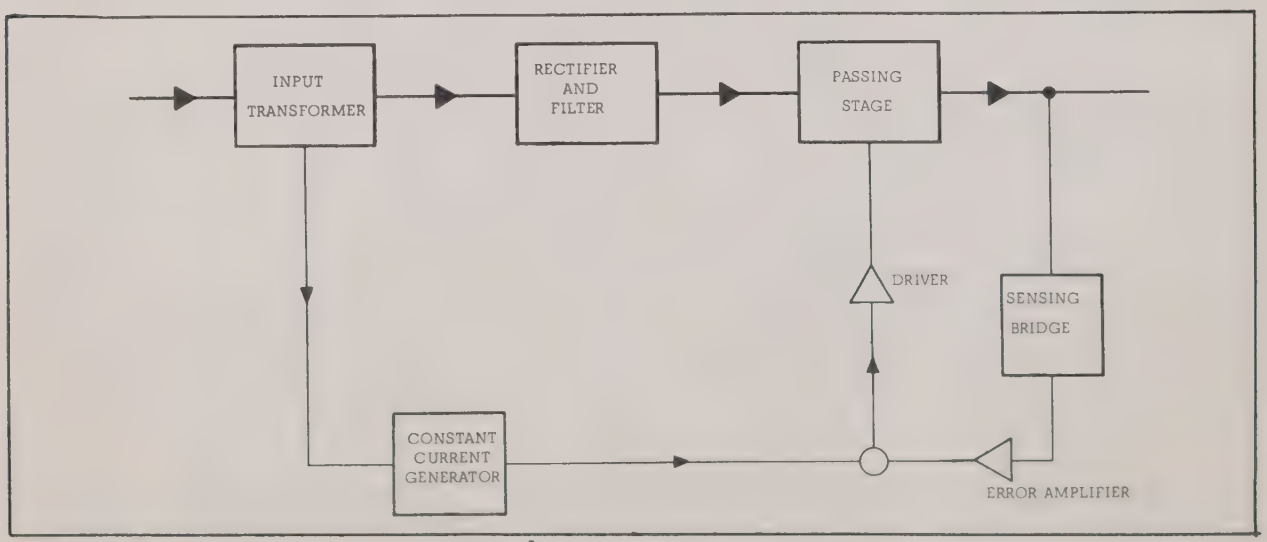


Figure 4-2. Block Diagram.

SECTION V
MAINTENANCE

5-1. GENERAL.

5-2. This section provides troubleshooting data, periodic servicing, and calibration and performance testing procedures. The troubleshooting data should be used in conjunction with both the schematic diagram (Figure 5-3), which tabulates voltage check points, and Section IV, which outlines the principles of operation. In addition, Figures 5-1 and 5-2 physically locate the parts appearing on the schematic. Any questions per-

SYMPTOM		POSSIBLE CAUSE
No output, fuses not blown	a.	No input.
	b.	Input Power Switch off.
	c.	Transistor Q1 open.
	d.	Rectifier CR1 open.
	e.	10-volt secondary of transformer T1 shorted. Capacitor C1 shorted.
	f.	Transistor Q4, Q3 (1) or Q2 (1) open.
	g.	Potentiometer R15 open.
No output, fuse F1 or F2 blown	a.	Unit overloaded; reduce load.
	b.	Rectifier CR6 or CR7 (2) shorted.
	c.	Capacitor C3 or C7 shorted.
	d.	See High Output Voltage.
Low Output Voltage	a.	Transistor Q6 or Q9 shorted.
	b.	Zener CR8 shorted.
	c.	Transistor Q7 or Q8 open.
	d.	Rectifier CR1 shorted.
High Output Voltage	a.	Defective potentiometer R18.
	b.	Potentiometer R15 wiper open.
	c.	Transistor Q6 or Q9 open.
	d.	Zener CR8 open.
	e.	Transistor Q7 or Q8 shorted.
	f.	Rectifier CR2 or CR3 open.
Output Oscillations	a.	Defective stabilization capacitor C4,
	b.	C5, C13, C14, or C8.
	b.	Output capacitor C7 defective.
High Output Ripple	a.	Rectifier CR6 or CR7 (2) open.

(1) When replacing transistor Q2 or Q3, apply 1 or 2 drops of silicone oil to mating surfaces. Use 200 Silicone Fluid, Dow Corning Co., Midland, Michigan, or an equivalent. Torque mounting screws to 8 lb-in.

(2) When replacing rectifier CR6 or CR7, apply a few drops of silicone oil on each side of mica washers and torque mounting nut to 13-14 lb-in.

Table 5-1. Troubleshooting Data

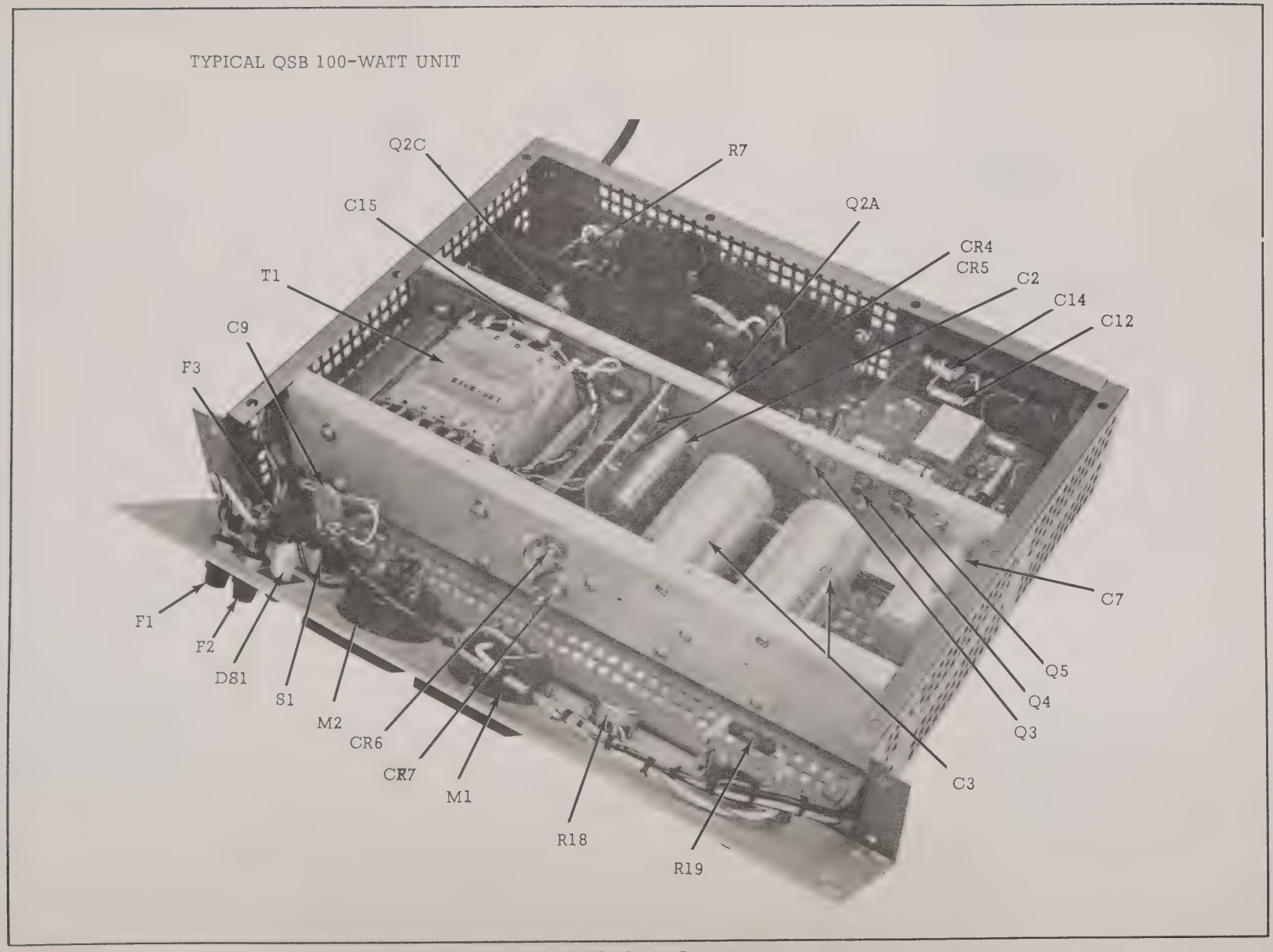


Figure 5-1. Parts Location.

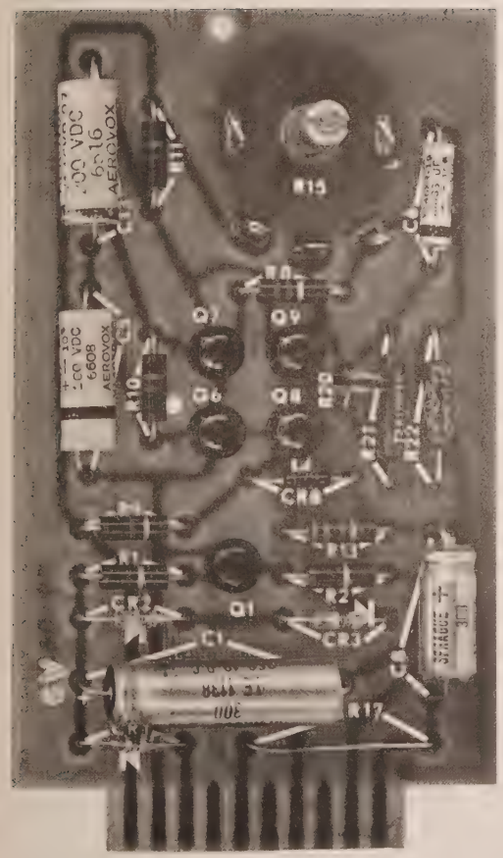
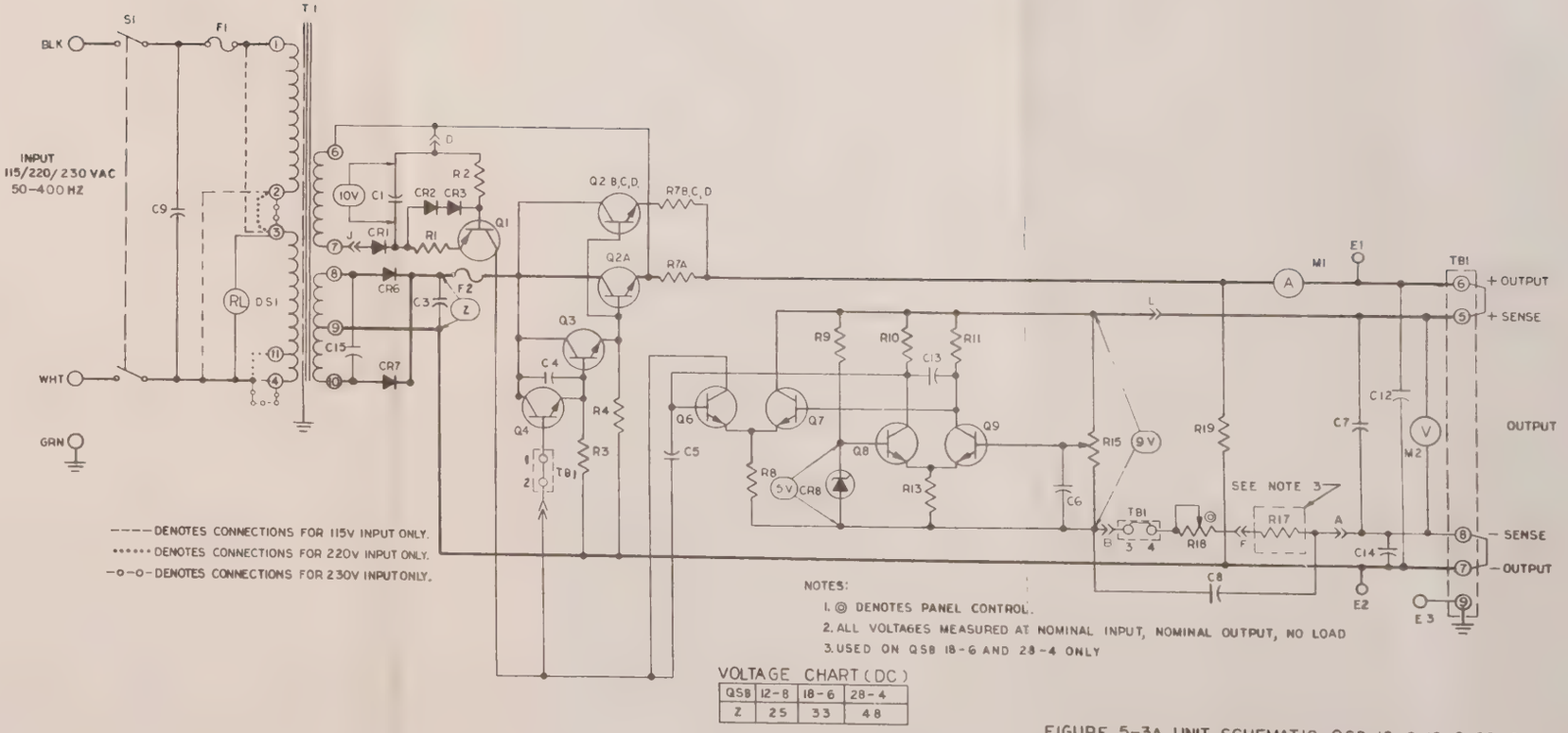


Figure 5-2. Component Board.



VOLTAGE CHART (DC)

QSB	12-8	18-6	28-4
Z	25	33	48

FIGURE 5-3A. UNIT SCHEMATIC, QSB 12-8, 18-6, 28-4

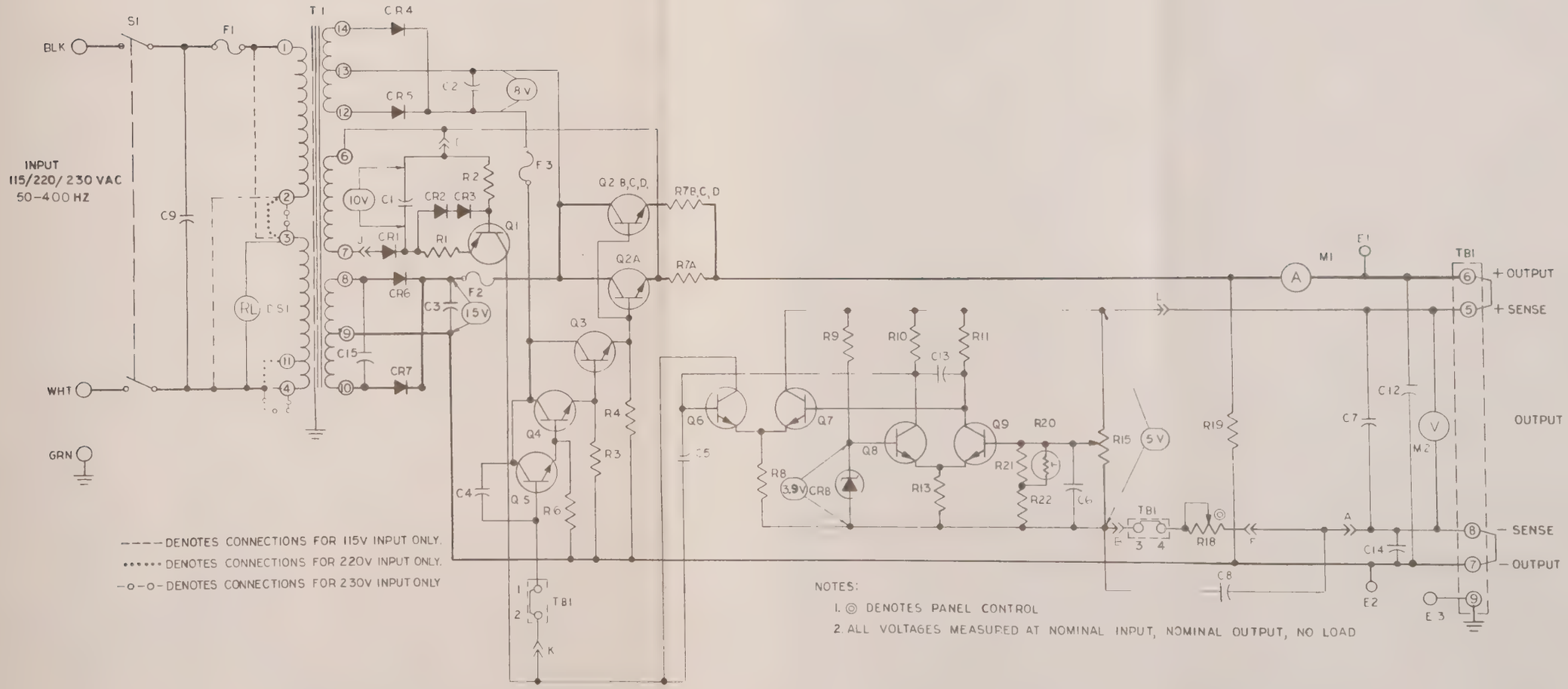


FIGURE 5-3B. UNIT SCHEMATIC, QSB 6-15.

taining to repair should be directed to nearest Sorensen representative (a list is included with the unit) or to the Service Dept., Raytheon Co., Sorensen Operation, Richards Ave., Norwalk, Connecticut, 06856. Include the model and serial numbers in any correspondence. Should it be necessary to return a unit to the factory for repair, authorization from Sorensen Service Dept. must be obtained first. Raytheon Company will not assume responsibility for units returned without prior authorization.

5-3. PERIODIC SERVICING.

5-4. No periodic servicing of QSB 25- and 50-watt units is required. However, it is recommended that, whenever a unit is taken off the line, it be cleaned. Use naptha, or an equivalent solvent, on painted surfaces and a weak solution of soap and warm water to wash the front panel. Use compressed air at a pressure of about 5 psi to blow dust out from in and around components.

5-5. TROUBLESHOOTING.

5-6. Table 5-1 provides a list of malfunction symptoms along with a tabulation of the possible cause or causes of each symptom. Note that the failure of one component may possibly cause the failure of another. This is the so-called "chain-reaction" effect. For example, an open Q2A may possibly cause the overloading and subsequent failure of Q2B, Q2C or Q2D. All should be checked before returning unit to line. The same effect may be noted in the main rectifier circuit. A failure of either CR6 or CR7 may damage the complementary rectifier and, in addition, the main transformer.

5-7. CALIBRATION.

5-8. To calibrate a QSB unit, proceed as follows:

a. Remove cover.

b. Set VOLT ADJUST potentiometer to center of range.

c. Connect a d-c voltmeter across terminals 3 and 5 on the rear-mounted external terminal board. Select a 10 V range.

d. With no load on unit, insert power-cord plug into a 115 Vac receptacle. Set POWER Switch to ON position.

e. Adjust potentiometer (R15) located on component board to obtain a voltmeter indication of 5 $\pm$ .1 volts for six-volt units and 9 $\pm$ .1 volts for all other units. Apply locking compound to R15.

f. Reset voltmeter range to 40 V, and reconnect across terminals 6 and 7.

g. Rotate VOLT ADJUST potentiometer from stop-to-stop. At left-hand stop, meter should indicate a value equal to or less than that of the low end of unit extended range (im-

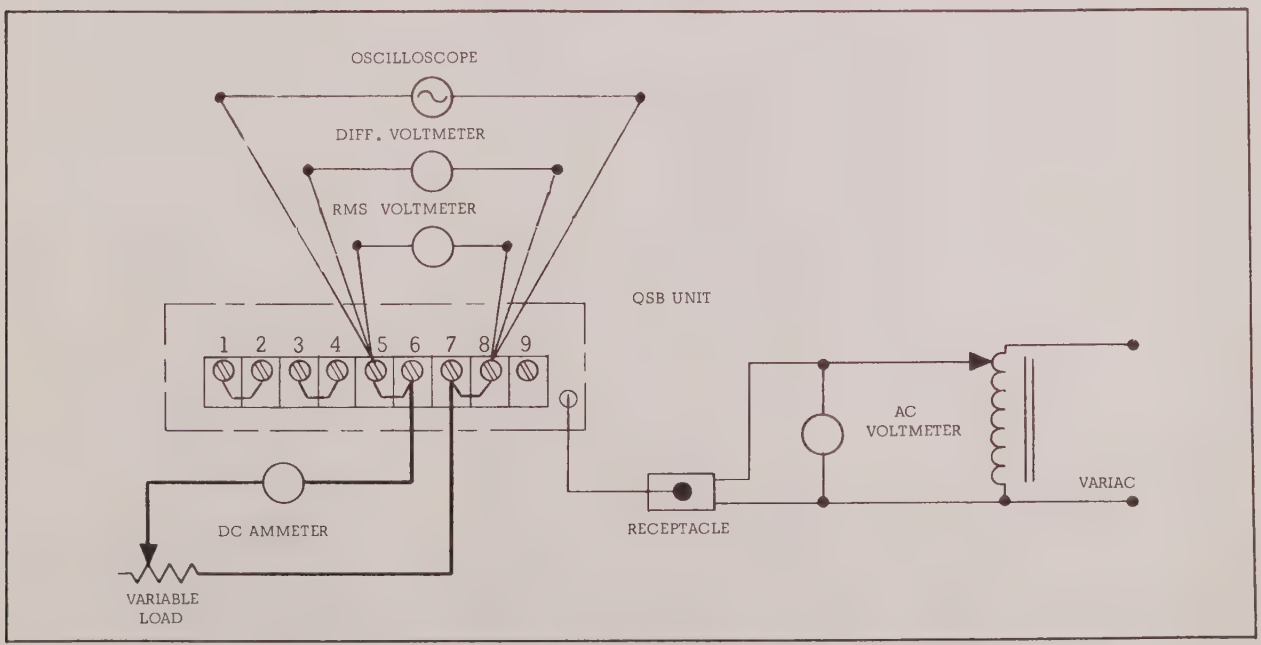


Figure 5-4. Output Ripple Test Set-up.

QSB MODEL	Nominal DC Output		Output Ripple (mV)		Regulation (mV)
	Volt	Amps	RMS Volt	Peak-to-Peak	
6-15	6	15	0.25	1.0	1.8
12-8	12	8			1.2
18-6	18	6			1.8
28-4	28	4			2.8

Table 5-2. Performance Test Specifications.

printed on front panel). At right-hand stop, the meter should indicate a voltage equal to or greater than the high end of unit extended range.

h. Set unit POWER Switch to OFF. Disconnect voltmeter. Remount cover.

5-9. PERFORMANCE TESTING.

5-10. OUTPUT RIPPLE. To measure unit output ripple, proceed as follows:

a. Connect a test set-up as shown in Figure 5-4. Set oscilloscope for 0.5 mV, vertical, and 10 mS/cm, horizontal. Select a 150 V range on AC input voltmeter. Choose a 0.5 mV range for RMS meter, and select a d-c ammeter range compatible with unit output. The Variac must be able to supply from 105 to 125 V ac at 3 A. Use a resistive load with a current drawing capacity equal to at least the nominal rated output of unit under test. Use differential voltmeter as a TVM (or VTVM). Select a range compatible with unit output.

b. Apply a 115 V ac input.

c. Set unit POWER Switch to ON.

d. At no load, adjust unit output to nominal output voltage (nominal output voltages are listed in Table 5-2).

e. Increase load until ammeter indicates nominal rated output current (refer to Table 5-2).

f. Observe oscilloscope and RMS voltmeter. Voltmeter should indicate no more than 0.25 mV; oscilloscope should display a peak-to-peak voltage not greater than 1 mV.

g. If a regulation test is to be performed, disconnect oscilloscope and RMS voltmeter, and refer to para 5-11. Otherwise, set input POWER Switch to OFF and disconnect test set-up.

5-11. REGULATION. To determine unit's output regulation, proceed as follows:

a. Connect unit to test set-up shown in Figure 5-4. The oscilloscope and RMS voltmeter are not necessary. Convert the differential voltmeter to act as a precision potentiometer. Select an internal voltage equal to the nominal unit output voltage, and set the null sensitivity to 10 mV range. (Refer to Table 5-2 for nominal output voltage).

b. Apply a 115 Vac input.

c. Set unit POWER Switch to ON.

d. At no load, adjust unit output to obtain a null indication on voltmeter.

e. With the a-c voltmeter indicating 115 Vac, increase load on unit until d-c ammeter reads the nominal rated output current. Record deviation from voltmeter null position.

f. Adjust voltmeter internal voltage to regain null position. Then, with full load on unit, vary the unit input voltage at 60 Hz from 105 to 125 V ac. Note the deviation.

g. Sum the deviations in steps "e" and "f". The total should be less than that stipulated in Table 5-2 for the unit under test.

h. Set unit POWER Switch to OFF. Disconnect test set-up.

SECTION VI

REPLACEMENT PARTS LIST

6-1. GENERAL.

6-2. This section provides a replacement parts list for the 100-watt QSB units. The list is keyed to both the parts-locating photographs (Figure 5-1 and 5-2) and the schematic diagram (Figure 5-3).

6-3. MANUFACTURER CODING.

6-4. The column headed MFR. CODE contains a listing of letter designators which, when applied to the tabulation that follows, will give the manufacturer from whom a particular item may be purchased. If no manufacturer's part number is listed in the MANUFACTURER PART NO. column, the part may be ordered from the indicated manufacturer by using the Sorensen part number and a complete description of the item.

AB	Allen Bradley Company
AX	Aerovox Corp.
BM	Bussman Manufacturing Div. McGraw Co.
CH	Cutler-Hammer, Inc.
CS	Clarostat Manufacturing Co., Inc.
FC	Fairchild Semiconductor
IRC	International Resistance Co.
KC	Keystone Carbon Co., Thermistor Div.
LF	Littelfuse Co.
MA	Motorola Semiconductor Products
RCA	Radio Corporation of America
RDM	Radio Material Co., Div. P.R. Mallory
RT	Raytheon Company
SG	Sage Electronics Corporation
SP	Sprague Electric Company
SR	Sorensen Operation, Raytheon Company
ST	Solitron Devices, Incorporated
WL	Ward Leonard Electric Co.

6-5. ORDERING PARTS.

6-6. When ordering parts from Raytheon Co., Sorensen Operation, include manufacturer's part number, the Sorensen part number and the unit model number. Address orders to:

Raytheon Company
Sorensen Operation
Richards Avenue
Norwalk, Connecticut 06856

REF. DES.	QSB MODELS				DESCRIPTION	SORENSEN PART NUMBER	MANUFACTURER PART NUMBER	MFR. CODE
	6-15	12-8	18-6	28-4				
C1	X	X	X	X	Cap., 250μF, 12 wVdc	24-2276-18		SP
C2	X				Cap., 3.4 mF, 10 wVdc	24-2458-1		SP
C3	X				Cap., 21 mF, 15 wVdc	24-2454-3		*
		X			Cap., 10 mF, 30 wVdc	24-2444-2		*
			X		Cap., 10 mF, 50 wVdc	24-2445-4		*
				X	Cap., 5 mF, 50 wVdc	24-2445-2		*
C4	X				Cap., 0.001 μF, 200 wVdc	24-2409-1		AX
		X	X	X	Cap., 0.0068 μF, 200 wVdc	24-2409-6		AX
C5	X				Cap., 0.047 μF, 200 wVdc	24-2409-11		AX
		X	X	X	Cap., 0.033 μF, 200 wVdc	24-2409-10		AX
C6	X	X	X	X	Cap., 0.0033 μF, 200 wVdc	24-2409-4		AX
C7	X				Cap., 6.4 mF, 15 wVdc	24-2454-4		*
		X			Cap., 3.4 mF, 25 wVdc	24-2544-2		*
			X		Cap., 3 mF, 30 wVdc	24-2444-3		*
				X	Cap., 1.7 mF, 40 wVdc	24-2445-6		*
C8	X				Cap., 75 μF, 6 wVdc	24-2275-14		SP
		X			Cap., 20 μF, 12 wVdc	24-2276-10		SP
			X	X	Cap., 25 μF, 25 wVdc	24-2279-10		SP
C9	X	X	X	X	Cap., 0.02 μF, 900 Vac	24-026		RDM
C12	X	X	X		Cap., 50 μF, 25 wVdc	24-2279-12		SP
				X	Cap., 50 μF, 50 wVdc	24-2280-12		SP
C13	X	X	X	X	Cap., 0.068 μF, 200 wVdc	24-2409-12		AX
C14	X				Cap., 0.033 μF, 200 wVdc	24-2409-10		AX
		X	X	X	Cap., 0.0068 μF, 200 wVdc	24-2409-6		AX
C15	X	X	X	X	Cap., 0.22 μF, 200 wVdc	24-2409-15		AX
CR1,2,3	X	X	X	X	Rectifier	26-1017	RD 9119	RT
CR4,5	X				Rectifier	26-1027-3	HC 67	ST
CR6,7	X				Rectifier	26-1046-1	MR 1120	MA
		X	X		Rectifier	26-1046-2	MR 1121	MA
				X	Rectifier	26-1046-4	MR 1122	MA
CR8	X				Rectifier	26-233	1N748A	MA
		X	X	X	Rectifier	26-211	1N750A	MA

* Capacitor may be ordered by description and Sorensen part number from either Aerovox Corp., Cornell-Dubilier Electronics or Sprague Electric Co.

Table 6-1. Replacement Parts List (Sheet 1 of 3)

REF. DES.	QSB MODELS				DESCRIPTION	SORENSEN PART NUMBER	MANUFACTURER PART NUMBER	MFR. CODE
	6-15	12-8	18-6	28-4				
DS1	X	X	X	X	Pilot Light Assembly (red)	43-308		SR
F1	X	X	X	X	Fuse, 5 A, 250 V	42-413	312005	LF
F2	X				Fuse, 20 A, 125 V, Type MBO	42-1846-4		BM
		X			Fuse, 10 A, 250 V, Type MBO	42-1846-1		BM
			X		Fuse, 8 A, 250 V, Type MBO	42-1846-2		BM
				X	Fuse, 5 A, 250 V	42-413	312005	LF
F3	X				Fuse, 1 A, 250 V, Type AGC	42-880		BM
Q1	X	X	X	X	Transistor	18-143	2N3638	FC
Q2	X	X	X	X	Transistor	18-151	2N3055	RCA
Q3	X	X	X	X	Transistor	18-142	40312	RCA
Q4	X	X	X	X	Transistor	18-145	RT 9343	RT
Q5	X				Transistor	18-145	RT 9343	RT
Q6,7, 8,9	X	X	X	X	Transistor	18-144	FSC 3641	FC
R1	X	X	X	X	Resistor, 150 ohm, 1/2 W	27-183	EB 1511	AB
R2	X	X	X	X	Resistor, 1.2 kohm, 1/2 W	27-1110	EB 1221	AB
R3	X				Resistor, 1 kohm, 1/2 W	27-103	EB 1021	AB
		X			Resistor, 2.2 kohm, 1/2 W	27-152	EB 2271	AB
			X		Resistor, 3.3 kohm, 1/2 W	27-140	EB 3321	AB
				X	Resistor, 3.3 kohm, 1 W	27-292	GB 3321	AB
R4	X				Resistor, 270 ohm, 1 W	27-718	GB 2711	AB
		X			Resistor, 390 ohm, 2 W	27-364	HB 3911	AB
			X		Resistor, 560 ohm, 2 W	27-1164	HB 5611	AB
				X	Resistor, 820 ohm, 3 W	27-397-95		WL
R6	X				Resistor, 10 kohm, 1/2 W	27-133	EB 1031	AB
R7	X				Resistor, 0.27 ohm, 7 W	27-470-11		WL
		X	X	X	Resistor, 0.56 ohm, 3 W	27-397-19		WL
R8	X				Resistor, 270 ohm, 1/2 W	27-191	EB 2711	AB
		X	X	X	Resistor, 680 ohm, 1/2 W	27-156	EB 6811	AB
R9	X				Resistor, 100 ohm, 1/2 W	27-173	EB 1011	AB
		X	X	X	Resistor, 180 ohm, 1/2 W	27-190	EB 1811	AB
R10,11	X				Resistor, 220 ohm, 1/2 W	27-1171	EB 2215	AB
		X	X	X	Resistor, 470 ohm, 1/2 W	27-166	EB 4711	AB
R13	X				Resistor, 680 ohm, 1/2 W	27-1152	EB 6815	AB
		X	X	X	Resistor, 1 kohm, 1/2 W	27-103	EB 1021	AB

Table 6-1. Replacement Parts List (Sheet 2 of 3)

REF. DES.	QSB MODELS				DESCRIPTION	SORENSEN PART NUMBER	MANUFACTURER PART NUMBER	MFR. CODE
	6-15	12-8	18-6	28-4				
R15	X	X	X	X	Pot., 200 ohm, 2 W	29-392		CS
R17			X		Resistor, 40 ohm, 3 W	27-383		SG
				X	Resistor, 90 ohm, 3 W	27-384		SG
R18	X				Pot., 100 ohm, 2 W	29-394		CS
		X			Pot., 150 ohm, 2 W	29-391		CS
			X		Pot., 200 ohm, 2 W	29-393		CS
				X	Pot., 300 ohm, 2 W	29-395		CS
R19	X				Resistor, 12 ohm, 7 W	27-470-51		WL
		X			Resistor, 100 ohm, 7 W	27-470-73		WL
			X	X	Resistor, 180 ohm, 7 W	27-470-79		WL
R20	X				Thermistor, 100 ohm	28-1088	RL3B1	KC
R21	X				Resistor, 200 ohm, 1/2 W	28-1052-56		IRC
R22	X				Resistor, 332 ohm, 1/2 W	28-1052-55		IRC
S1	X	X	X	X	Switch, DPST	45-112	7561K5	CH
S2	X	X	X	X	Thermostat	92-517		SR
T1	X				Transformer	126-2912		SR
		X			Transformer	126-2913		SR
			X		Transformer	126-2914		SR
				X	Transformer	126-2915		SR
XF1	X	X	X	X	Holder, fuse	42-459	342012	LF
XF2	X	X	X	X	Holder, fuse	42-459	342012	LF
XF3	X				Holder, fuse	42-459	342012	LF
					OPTIONAL PARTS			
M1	X				Ammeter, 0 - 20 A	94-433-5		SR
		X			Ammeter, 0 - 10 A	94-433-4		SR
			X		Ammeter, 0 - 8 A	94-433-9		SR
				X	Ammeter, 0 - 5 A	94-433-3		SR
M2	X				Voltmeter, 0 - 10 V	94-549-1		SR
		X			Voltmeter, 0 - 20 V	94-549-2		SR
			X		Voltmeter, 0 - 30 V	94-549-7		SR
				X	Voltmeter, 0 - 40 V	94-549-3		SR

Table 6-1. Replacement Parts List (Sheet 3 of 3)

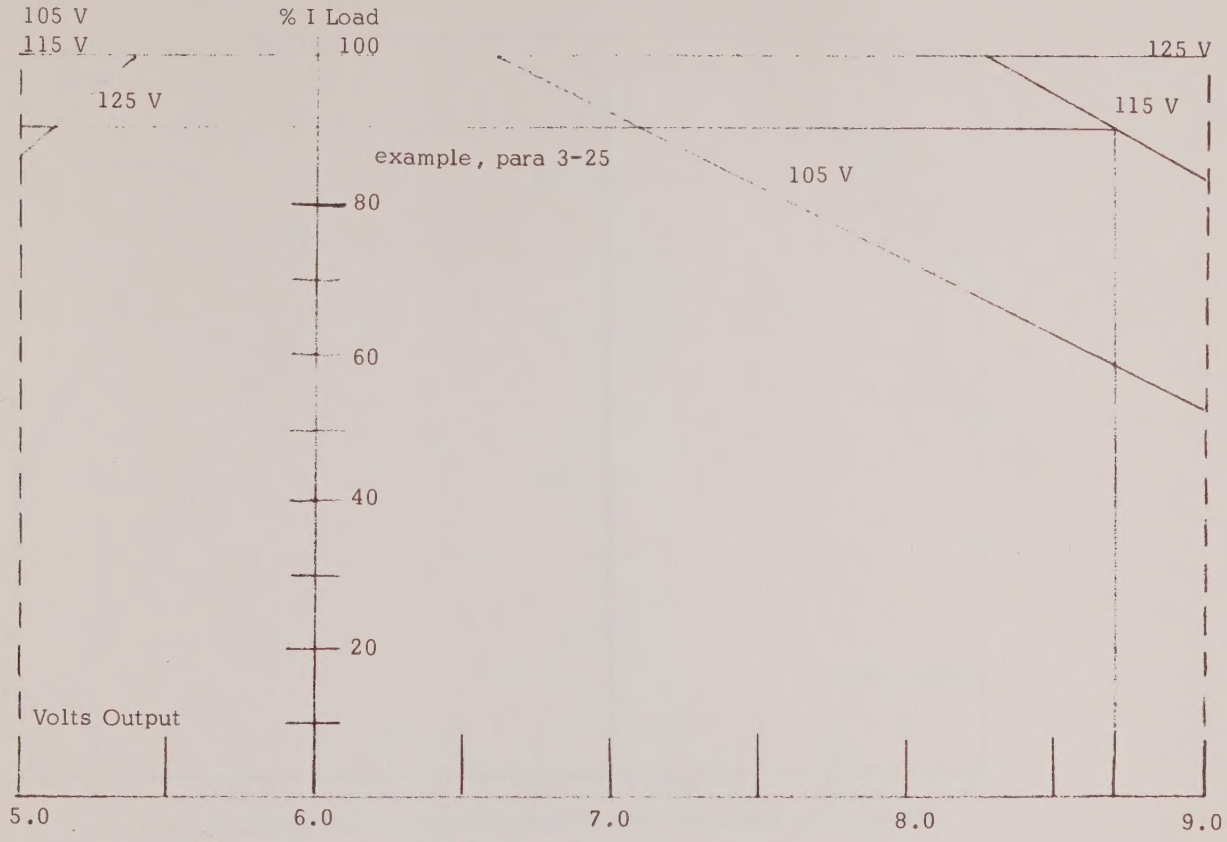


Figure A-1. Extended Range Characteristics, QSB 6-15. (Typical)

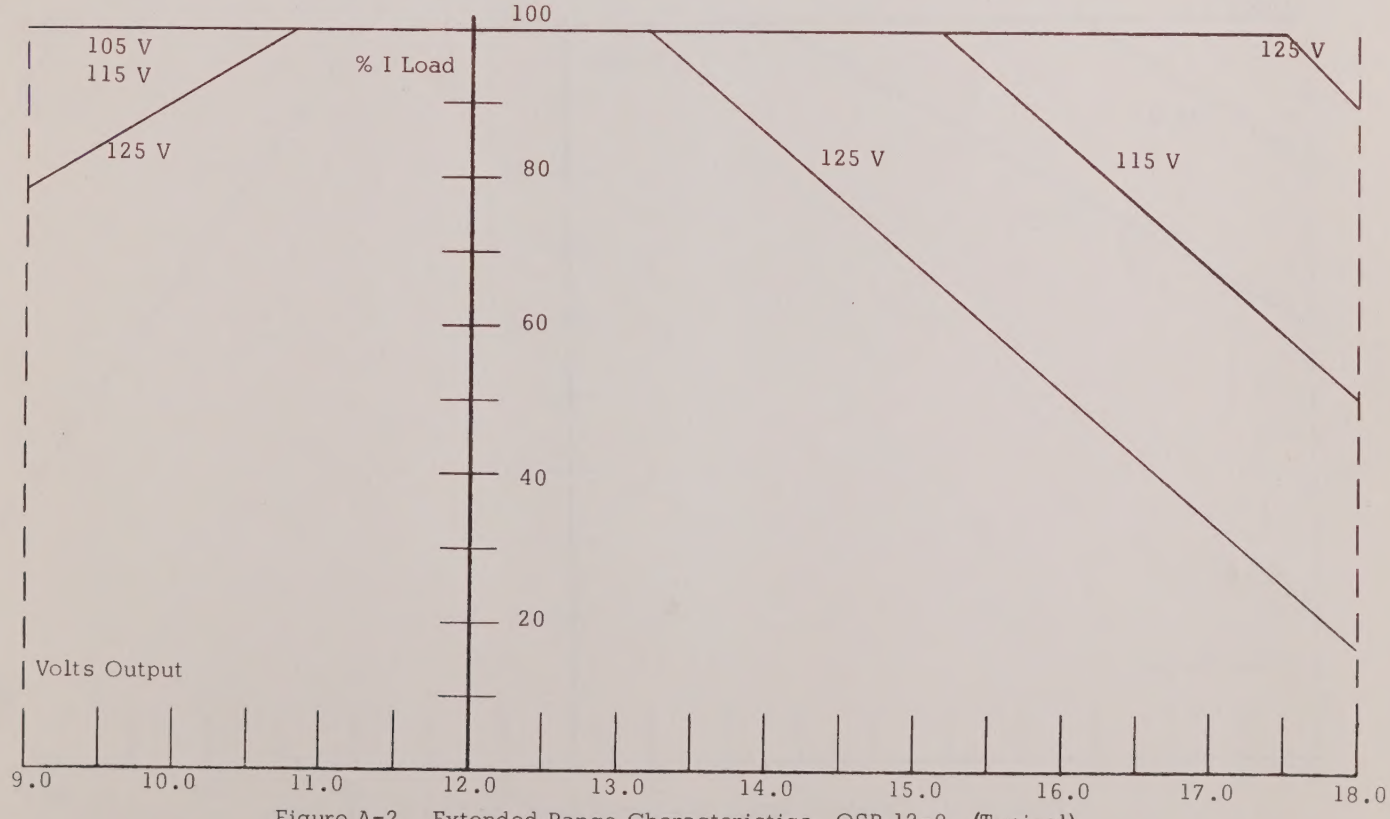


Figure A-2. Extended Range Characteristics, QSB 12-8. (Typical)

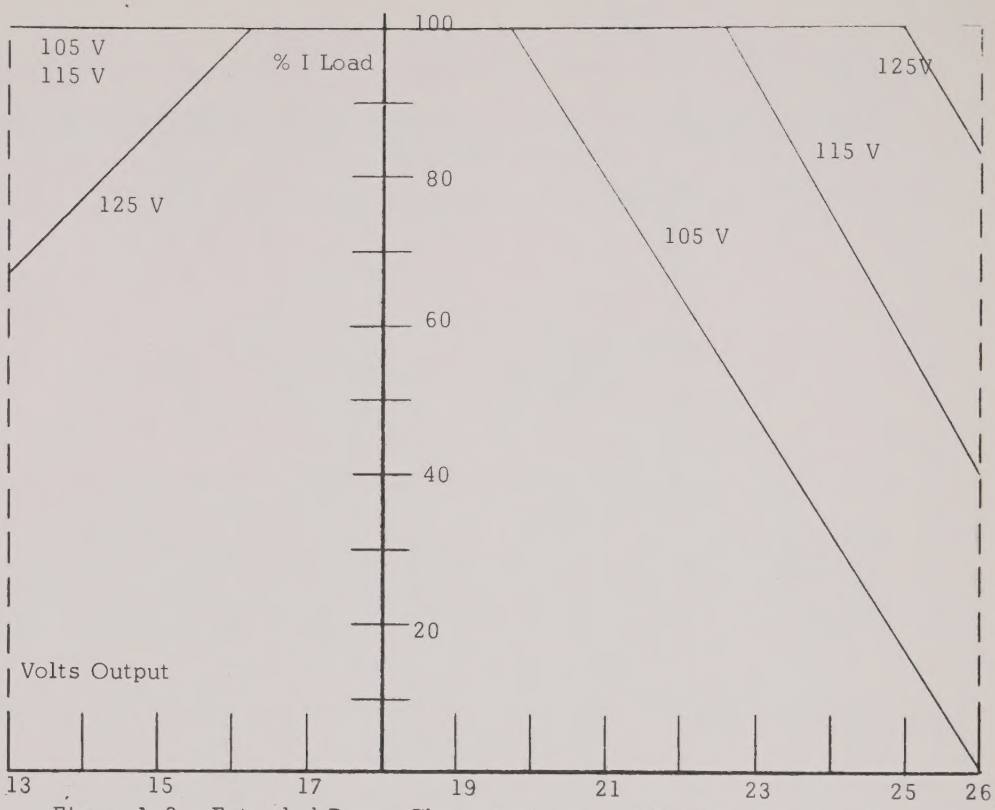


Figure A-3. Extended Range Characteristics, QSB 18-6. (Typical)

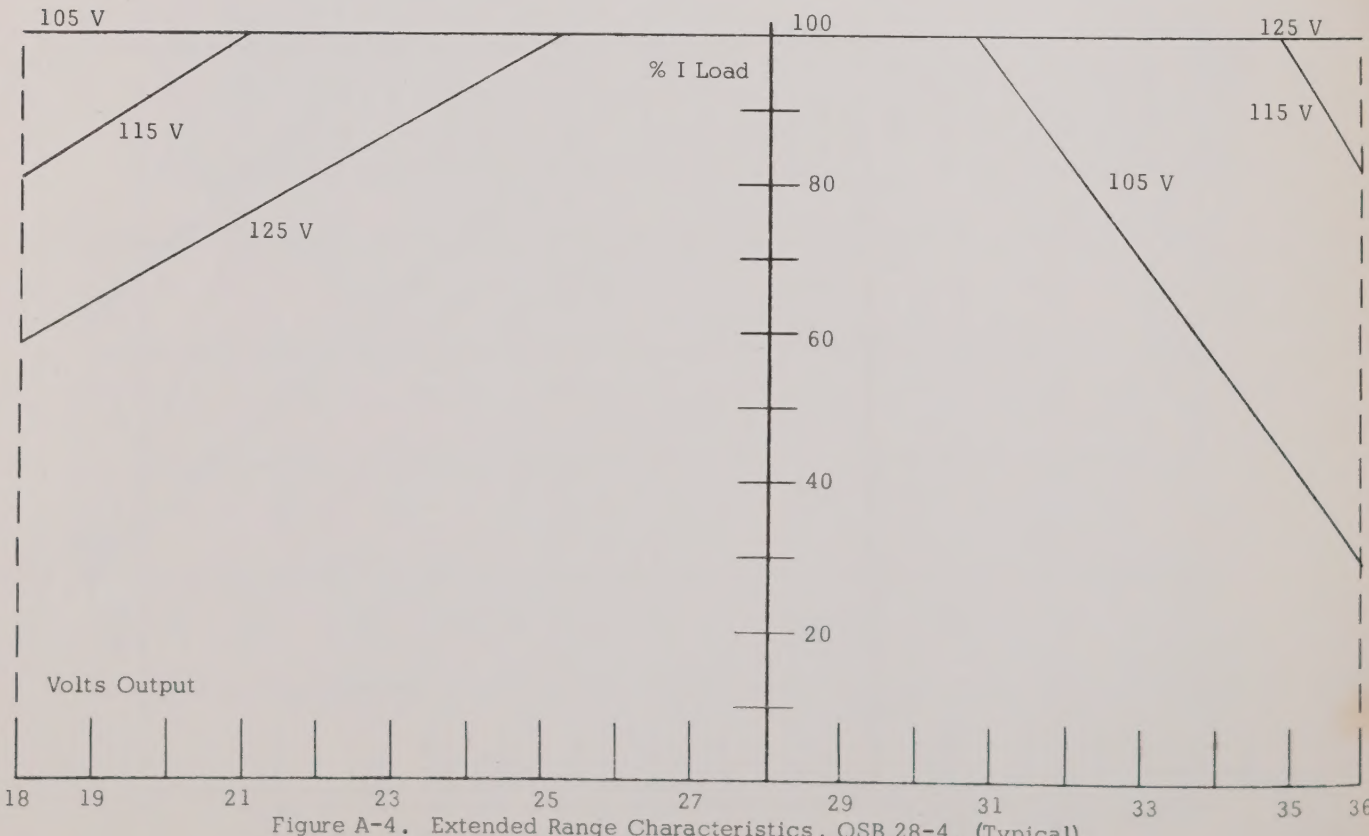


Figure A-4. Extended Range Characteristics, QSB 28-4. (Typical)

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